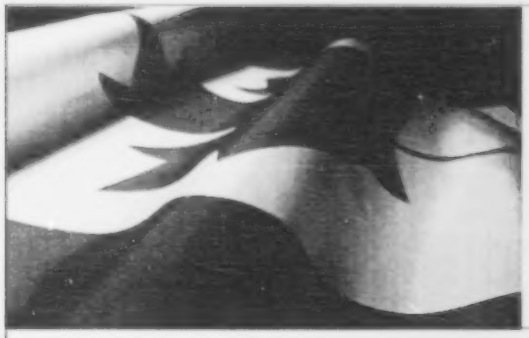

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Ranking Tax Distortions in Dynamic General Equilibrium Models: A Survey [1]

by

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Abstract

This paper surveys dynamic computable general equilibrium analyses of tax distortions, focussing on the issue of tax ranking. Results from standard neo-classical growth models and human-capital driven endogenous growth models are reviewed. In general, the ranking based on results from neo-classical growth models indicates that capital taxes are the most distortionary, followed by labour and then consumption taxes. Tax ranking based on results from endogenous growth models, on the other hand, are more heterogeneous and vary across framework, settings, and ranking criteria. Nonetheless, results from these models indicate that both capital and labour tax reductions tend to have greater economic impacts than consumption tax reductions.

Résumé

Ce mémoire fait le survol de travaux qui classent les distorsions causées par les taxes à l'aide de modèles d'équilibre général dynamiques calculables. Le survol examine les résultats provenant de modèles néo-classiques ainsi que ceux provenant de modèles de croissance endogène où le capital humain est la force motrice. Le classement provenant de modèles néo-classiques indique qu'en général, les taxes sur le capital sont les plus distorsionnaires, suivie des taxes sur le travail et des taxes sur la consommation. En revanche, le classement provenant de modèles de croissance endogène est plus hétérogène et varie selon le cadre d'analyse et les critères de sélection. Néanmoins, ces derniers indiquent que la réduction des taxes sur le capital et le travail engendre des retombées économiques plus importantes que la réduction des taxes sur la consommation.

I. Introduction

General equilibrium models are useful tools for tax policy analysis and, as such, are used extensively in both academia and government. In particular, they represent an excellent tool for determining which tax measures are most distortionary from an efficiency standpoint. However, given the plethora of general equilibrium models in existence a natural question arises: how consistent are results from different models and to what extent do different assumptions affect their key conclusions?

It is a well-known fact that the results of computable general equilibrium (CGE) models can be very model specific. The choice of the theoretical framework that underpins the functioning of a model is of critical importance since different frameworks can lead to different results. In addition, because different models tend to refine some areas and simplify others, different results can be obtained even within the confines of a given theoretical framework. Similarly, analogous frameworks can yield different results if applied to different settings (i.e., countries) since calibration and parameterization play an important role.

Prima facie, the above appears to answer the question at hand. Upon examining the literature more closely, however, one realises that such an answer dissimulates some insightful trends and consistencies. A more cogent answer to the aforementioned question would take a broader view and examine the literature with an eye towards identifying some general trends rather than attempting to establish unanimity.

Scope of Analysis

In what follows, the literature is examined with this broader perspective in mind. However, in order to remain brief and keep the analysis tractable, the scope of the inquiry is limited in several ways. First, only dynamic CGE models are considered. Although static models remain useful for the analysis of inter-sectoral and inter-asset distortions, they are ill equipped to assess the dynamics of saving and investment. As a result, dynamic CGE models have become the standard tool for tax policy analysis. Second, most of the inquiry will be limited to the issue of tax ranking based on marginal efficiency of the various tax policy alternatives. Therefore, the closely related literature of optimal taxation (in the Ramsey (1927) sense) and fundamental tax reform is ignored and is left for future work.

Addressing the issue of result consistency and robustness of CGE models is a difficult task. A comprehensive assessment would require fitting the myriad of existing frameworks to a particular economy at a particular point in time, simulating equivalent tax experiments and reporting the results in a standardized fashion. Since such a task is precluded by its enormity, one must veer towards cruder methods of comparison. In academia, researchers rank taxes according to their efficiency, where efficiency is either measured by the welfare losses arising from a tax or a marginal excess burden type concept. Conceptually, such measures are ideal. Unfortunately, there is no standardized measure used by all. Thus, rankings from the literature use similar, but not identical, concepts of efficiency. In addition, to avoid having to pick a certain welfare concept, taxes can also be ranked according to their impacts on steady-state output. Although a ranking based on such a measure differs from traditional efficiency approaches, the key message is often the same so that the substitution between measures is

fairly innocuous. Unless noted otherwise, efficiency rankings in this paper refer to rankings based on welfare or marginal excess burden type calculations. Evidently, the concept and measure on which the tax ranking is based will vary from study to study and therefore results are not directly comparable. However, despite the differences, some trends and consistencies do emerge.

Overview

This review begins with the neo-classical growth literature and finds that it paints a fairly consistent picture. All but one of the seven studies reviewed find that capital taxes are less efficient than labour taxes, which are less efficient than consumption taxes. Furthermore, although a smaller number of studies examine the issue, personal capital taxes are generally found to be less efficient than corporate income taxes. It is worth emphasizing, however, that both of the above two trends are bucked by a recent study of tax distortions in the United States. Incidentally, although only three studies examine the issue, investment tax incentives are found to be highly effective. Finally, the ranking of tax policies does not appear to be sensitive to whether they are ranked according to their efficiency or their impact on steady state output.

In the subsequent section, attention is turned to the motley endogenous growth literature. Unlike its neo-classical counterpart, the endogenous growth literature has not yet settled upon a particular paradigm and most of the efforts have focussed on identifying the engines of growth and on whether or not tax policy, in general, can affect these engines. The focus is on the strand of the endogenous growth literature in which human capital is the engine of growth. This literature is divided into two camps. The first purports that tax policy does not affect growth permanently in any significant way but that there are permanent level effects as in the neo-classical growth framework. In this camp, the tax ranking mirrors the general consensus in the neo-classical literature. The second camp, on the other hand, professes that tax policy can have non-trivial growth effects. Unfortunately, work examining the tax ranking issue in such a context is limited. The little work that does examine the issue raises two possibilities. One possibility raised is that, although growth effects for certain tax policies are non-trivial, the difference between these growth effects are small so that the efficiency ranking of factor taxes again reflects level effects and accords with that of the neo-classical growth literature. The second possibility is that growth effects vary enough across tax experiments to override level effects. Rankings based on growth effects suggest that reducing capital or labour taxes has a greater impact on steady-state growth than reducing consumption taxes. However, although studies report that capital taxes generally rank ahead of labour taxes, the ranking varies across frameworks, countries, and methods used to offset the tax cut. Unfortunately, none of the studies surveyed offer a welfare ranking in such a context. Pending future research, it is hard to say anything about the efficiency ranking of various tax policies in an environment where the difference in the growth effects of such policies are non-trivial.

II. Results from the neo-classical growth literature

It is useful to begin the inquiry with two Canadian models developed at the Department of Finance. The reason for such a starting point is that research at the Department has focussed on Canadian tax policy and efforts have been made to report results on a comparable basis. As will be seen, this is far from being the case for results from the literature at large. In fact, since policy simulations are implemented in different ways and at different points in time, caution must be exercised in making direct comparisons between any of the studies presented below. Rather, the focus is cast on the similarities that emerge despite the discrepancies. Although the following survey is not exhaustive, it is representative of the state of this literature.

Matier and Wu (2000)[1] and Baylor and Beauséjour (2004)

These two models use the representative agent framework. The first model was introduced in James (1994) and used for tax policy assessment in Matier and Wu (2000). The second was developed in Baylor and Beauséjour (2004) for the express purpose of tax policy analysis. Both models were used to simulate the long-run impacts of 1%-of-GDP revenue equivalent deficit-neutral tax reductions. The results of the long-run impacts on GDP, consumption, and the private sector capital stock are reported in Table 1. The qualitative ranking according to welfare in both models is consistent with the ranking based on the consumption figures[2].

Table 1: Long-Run Impacts of Deficit-Neutral 1%-of-GDP Tax Reductions[1]

%Δ steady state level of:	Baylor & Beauséjour (2004)			Matier & Wu (2000)		
	GDP	**Consumption**	**Capital Stock**	**GDP**	**Consumption**	**Capital Stock**
Personal capital tax	3.4	2.5	6.9	2.1	4.11	7.4
Corporate income tax	1.9	1.3	3.8	1.3	0.6	4.3
Personal income tax	1.3	1.1	2.1	1.1	2.3	2.9
Wage Tax	0.7	0.6	0.6	0.7	1.4	1.4
Consumption Tax	0.2	0.2	-0.2	0.5	0.9	0.9

[1]The revenue loss is recovered through lump-sum taxes.

Despite the fact that the two models differ in many respects[3], the rankings (although not the magnitudes) of the policy shocks with respect to all three indicators are quite similar. The notable exception is the ranking of the effects of the corporate income tax shock on consumption; the discrepancy is primarily due to differences in the way foreign investment is modelled.

Baylor and Beauséjour (2004), also report results for an increase of tax depreciation rates (or CCA). This policy ranks first in terms of welfare gains. The percentage change in the steady-state levels of GDP, consumption, and the capital stock are 4.4%, 2.6%, and 8.6%, respectively.

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[1] Unlike the other models surveyed, Matier and Wu (2000) incorporate uncertainty and market imperfections. These include money demand, nominal wage rigidities, and stochastic portfolio returns.

[2] Baylor and Beauséjour (2003) report a welfare ranking but Matier and Wu (2000) do not.

[3] For example, Matier and Wu (2000) incorporate a probability of death, budget deficits, and heterogeneous agents but model production in a simplified, aggregate manner. Baylor and Beauséjour (2003), on the other hand, do not model the aforementioned aspects but model the multi-sector aspect of our economy.

Ballard, Shoven and Whalley (1985)

One of the first papers to use a dynamic CGE model to rank several tax measures in the United States was Ballard, Shoven and Whalley (1985). It examines the marginal excess burden (MEB) of all major taxes in the United States using a representative agent, multi-sector model. Results are reported in Table 2. Of course, the results can no longer be taken at face value since they are based on the economic and tax structure of the United States in 1973. Nonetheless, the literature still uses the model as a benchmark for comparison and it remains indicative of the type of results obtained in neo-classical growth models.

Table 2: Marginal Excess Burden from Raising Extra Revenue from Specific Portions of the Tax System[1]

	Marginal Excess Burden (MEB)
Capital Taxes at the industry Level[2]	0.463
Personal Income Taxes	0.314
Output Taxes[3]	0.279
Labour Taxes at the Industry Level[4]	0.230
Consumer Sales Taxes	0.388
Consumer Sales Taxes on Commodities other than Alcohol, Tobacco, Gasoline	0.115

[1] Distortionary taxes are raised and the additional revenue is used for non-distortionary government expenditures.
[2] Corporate income taxes and corporate franchise taxes.
[3] Excise taxes and other indirect business taxes and non-tax payments to government.
[4] Social security taxes, unemployment insurance, and worker's compensation.

Despite the fact that we have changed the framework, the period, and the reference country, the ranking based on the marginal excess burden (MEB) is similar to that of the Baylor and Beauséjour (2004) and Matier and Wu (2000) ranking based on steady-state GDP impacts. Unfortunately, the authors do not provide simulations for personal capital taxes. However, one can surmise that they are fairly distortionary since income taxes (which are a weighted average of personal capital taxes and personal labour taxes with most of the weight attributable to the latter) are significantly more distortionary than labour taxes (assuming personal labour taxes have a MEB similar to their industrial counterparts).

It should also be noted that the high MEB for the general consumer sales tax is entirely attributable to taxes on alcohol, tobacco, and gasoline[4]. Once these are removed, the sales tax becomes fairly benign.

Judd (1987)

This paper examines the marginal efficiency cost of taxes in a baseline representative agent, neo-classical growth model of the U.S. economy. Although the analysis is limited to a comparison of wage and capital taxes and the investment tax credit it is particularly relevant since it conducts a battery of sensitivity tests.

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[4] The tax on alcoholic beverages is 87.5%, on tobacco 95.8%, and on gasoline 29.5%. Ballard Shoven and Whalley (1985) emphasise that the simple way they model the above three taxes is highly contentious. Indeed, the taxes on alcohol and tobacco could be defended as Pigovian externality-correcting taxes while the gasoline tax is often viewed as a benefit-related fee for the use of roads.

In this instance, paraphrasing the author's findings and conclusions better summarizes the results than a table. Based on his calculations of the marginal deadweight loss for permanent tax policy changes, Judd (1987) finds that the wage tax has an efficiency cost of at most 50 cents per dollar of revenue and is usually less than 15 cents in the low case, whereas the capital income tax has an efficiency cost of at least 15 cents and usually more than 40 cents. He concludes "Given that empirical analysis support many of the parameter choices, these calculations show that there is little reason to have any quantitative confidence about the true excess burden for any tax instrument. Despite the large variance in the computed excess burdens, there are important robust qualitative implications. First, for all parameters the excess burden of permanent capital taxation substantially exceeds that of permanent wage taxation. Both pale, however, when compared with the results for the investment tax credit; in fact, an increase in the investment tax credit may increase revenues."[5]

Three observations are appropriate. First, the tax ranking, although much less detailed, is in accord with the other studies reviewed so far. Second, since investment tax credits are analytically equivalent to accelerated capital cost allowances, the results accord with Baylor and Beauséjour (2004). Third, his sensitivity results were obtained by varying three parameters: the elasticity of consumption demand, the elasticity of the labour supply, and the level of initial taxation. In addition, the author confirms the robustness of his results with respect to factor shares in production, depreciation, the elasticity of substitution between capital and labour, and the functional form of the utility function. To the extent that the above parameters properly account for differences between various countries, the results may be viewed as a test of robustness across countries. Indeed, given its simple structure, if one were to fit the Judd (1987) model to another country one would pretty much be limited to changes in the aforementioned parameters. Of course, the model would only be appropriate for closed economies. Nevertheless, his results are in accord with results for Canada (see Table 1).

Auerbach and Kotlikoff (1987)

The above studies all examine tax policy in a representative agent framework. Recall that the infinitely lived representative agent model can be thought of as a life cycle model with bequests where each generation cares about the utility of future generations (see Barro (1974)). However, since this may not be the case, it appears worthwhile to investigate whether switching to a less idealistic life cycle framework alters the results. To gain insight into the issue, it is useful to examine a model that lies at the other end of the spectrum. In their seminal book Auerbach and Kotlikoff (1987) develop a neo-classical growth, overlapping generations model of the U.S. economy with no bequests (each individual only cares about his own utility over the course of his lifetime). They use their model to simulate the effects of switching from one tax base to another. In particular, they consider switches from an income tax base (in their base case, the only tax is a proportional 15% income tax) to consumption, wage, and capital income tax bases. Their results are reported in Table 3.

The shocks involved are very large and are more akin to fundamental tax reform (rather than marginal excess burden type calculations) and therefore are somewhat different from the other

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[5] Judd (1987), p.696. See also his Table 1, p.695.

results reported in this section. Nonetheless, the figures suggest that a tax ranking in an OLG framework would mirror that observed in a representative agent framework. Indeed, Mérette (1997) reports that: "There is a common view in the literature which claims that although the Ramsey and OLG models have very different theoretical frameworks, they yield, in practice, quite similar results for tax problems."[6]

Table 3: Long-Run Impacts of Deficit-Neutral Shifts in the Tax Base

%Δ in the steady state level of:	Welfare	Capital Stock
Shift from income tax base to consumption tax base	2.32	24.2
Shift from income tax base to wage tax base	-0.9	6.3
Shift from income tax base to capital income tax base	-1.14	-36.8

Auerbach and Kotlikoff (1989) also present results supporting the high efficiency of investment incentives (accelerating CCA or an ITC). In particular, they show that providing full expensing on new investment (with the budget balanced maintained by adjusting the income tax rate) is equivalent to shifting from an income tax base to a consumption tax base (the first row of Table 3).

Jorgenson and Yun (1991, 2001)

The Jorgenson and Yun model was originally developed in Jorgenson and Yun (1986), it is a neo-classical growth, multi-sector, multi-asset, dynamic model of the U.S. economy expressly developed for tax policy analysis. In Jorgenson and Yun (1991), they calibrate their model using data covering the 1947-1986 period and estimate the marginal efficiency costs (MEC) of the various components of the U.S. tax system under the 1985 Tax Law. The results are given in the last column of Table 4. The ranking, although not the magnitudes, is identical to the welfare ranking reported in Baylor and Beauséjour (2004). From their results, Jorgenson and Yun (1991) concluded that: "Within the income tax at both the federal and state and local levels there is excessive reliance on taxes on capital income at the individual level. Taxes on capital income at both corporate and individual levels are too burdensome, relative to taxes on labour income."[7]

Using a new version of their 1986 model, calibrated using data covering the 1970-1996 period, Jorgenson and Yun (2001) estimate the MEC of the same components of the U.S. tax system under the 1996 Tax Law. As can be seen from Table 4, the results are strikingly different.

Unlike all the neo-classical growth models reviewed so far Jorgenson and Yun (2001) find that, as far as marginal efficiency cost goes, labour income taxes are most distortionary. It is important to note, however, that the ranking from Table 4 masks one of the key insights from their book: that large welfare gains can be attained through equalizing tax burdens across sectors and assets. In fact, the authors' key policy prescription[8] is to equalize all tax burdens on all forms of assets while minimizing the marginal tax rate on labour income, with emphasis on the former.

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[6] Mérette (1997), p.4. A similar affirmation is made in Lucas (1990), and Jones and Manuelli (1992).
[7] Jorgenson and Yun (1991), p.503.
[8] See Jorgenson and Yun (2001), p.18.

The theoretical frameworks used in both studies are very similar, they both have the same detailed representation of the tax system, use the same technique for selecting parameter values (by econometric methods), and both account for the progressivity of all taxes. The differences, therefore, arise from the updated econometric estimates and the changes in the United States Tax Law between 1985 and 1996. In particular, the higher labour supply elasticity in Jorgenson and Yun (2001) helps explain the larger MEC of the labour income tax. Unfortunately, it is, in general, virtually impossible to allocate the differences between the two studies to any specific set of parameters; there are simply too many interrelated parameters involved. There is thus no readily available explanation for the large difference in MEC for the individual capital income tax.[9]

Table 4: Marginal Efficiency Cost of Various Taxes in the United States[1]

	Marginal Efficiency Costs Jorgenson & Yun (2001)[2]	**Marginal Efficiency Costs Jorgenson & Yun (1991)[3]**
Labour Income Tax	0.404	0.376
Individual Income Tax	0.352	0.520
Corporate Income Tax[4]	0.279	0.448
Individual Capital Income Tax	0.264	1.017
Sales Tax (on both consumer and investment goods)	0.175	0.262

[1] The revenue loss is recovered through lump-sum taxes.
[2] Efficiency costs under the 1996 Tax Law.
[3] Efficiency costs under the 1985 Tax Law.
[4] When the corporate income tax is reduced, the tax credits on corporate investment are also reduced in the same proportion.

Given the apparent sensitivity[10] of the results to parameter values and the tax structure, there is no telling what kind of results a Jorgenson and Yun type model would yield if fitted to the Canadian economy.

Comparing experiments from neo-classical growth CGE models

In light of the above survey, four observations on the consistency of tax rankings across models and settings appear particularly relevant.

First, all but one of the studies reviewed find that capital taxes are less efficient than labour taxes, which are less efficient than consumption taxes.

Second, although a smaller number of studies examine the issue, personal capital taxes are generally found to be less efficient than corporate income taxes.

Third, the three studies that examine the issue find that investment incentives are highly effective. It need be emphasised, however, their effectiveness is conditional on incentives being

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[9] I am grateful to Kun-Young Yun for sharing his thoughts on the issue. It should be noted that although he could not reconcile the large difference in MEC for the individual capital income tax, he felt that the figure from Jorgensun and Yun (1991) might be too high.

[10] As Gravelle (2003) points out in her review of Jorgenson and Yun (2001), the authors do not provide any sensitivity analysis making it all but impossible to infer how changes might affect the outcome.

equalized across sectors and assets. If such is not the case, inter-asset and inter-sectoral distortions will dampen their efficacy (see Whalley (1997)).

These three observations hold for both Canada and (until recently) the United States[11]. Jorgenson and Yun (2001) contend that observations one and two no longer apply to the United States. Unfortunately, they fail to explain why things have changed so drastically over the last ten years.

Finally, although only two studies from the Department explore the issue, the ranking of tax policies does not appear to be sensitive to whether they are ranked according to their efficiency or their impact on steady-state output.

It is pertinent to close with a caveat regarding the consistency of results for Canada and the United States. In both models of the Canadian economy, Canada is modelled as a "quasi-closed economy"[12]. The reason is that empirical evidence does not support the predictions of the textbook small open economy model[13] and therefore is not modelled as such. However, modelling Canada in such a fashion would invalidate the second observation mentioned above. In his classic article Gordon (1986) shows that for a small open economy it is optimal to set the corporate income tax rate to zero while optimal personal capital taxes are positive. The intuition behind the optimality of a zero corporate income tax is that since the supply of capital from abroad is perfectly elastic, labour bears the entire burden of a tax on either labour or corporate income but a tax on corporate income creates a further distortion to capital-labour ratios.

III. Results from the endogenous growth literature

As alluded to in the introduction, the endogenous growth literature is incredibly diverse and has yet to settle upon any one paradigm. The focus of the literature has been on identifying the engines of growth and on whether or not tax policy, in general, can affect those engines. A good literature review on the subject, conducted by the Department, can be found in OECD (1997). The survey describes the myriad of frameworks in existence and explores the implications for taxes and government spending in each framework. The survey concludes that the growth effects of taxation and government spending depend critically upon model specification.

However, the implications of OECD (1997) for tax ranking are unclear. The conclusion that the effects of taxes are very model specific holds for a general income tax. This conclusion does not preclude, when a more detailed set of factor taxes is considered, a similar tax ranking in each framework or, more realistically, that a certain ranking is preserved in a majority of frameworks[14].

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[11] In addition, Judd (1987) shows that his results hold for an extensive range of parameters and functional forms. This may be interpreted as cross-country consistency.

[12] This arises from the imposition of preferences for domestic goods and assets.

[13] See, for example, Babineau and Durango (2002).

[14] Although a convincing discussion would have to extend the analysis and include R&D and education subsidies and account for the type of government spending that adjusts when tax rates change.

Unfortunately, there are few studies that explicitly explore the issue of tax ranking in the endogenous growth setting. Thus, unlike the neo-classical growth literature, one cannot simply sift through all available results and point to trends and consistencies. However, in the strand of the endogenous growth literature where human capital is the engine of growth, significant efforts have been made to quantify the growth effects of taxation and some relevant insights for those interested in the issue of tax ranking have emerged. A parallel, but unrelated, literature has also emerged in the strand of the literature where innovation through R&D is the engine of growth. Since human capital is usually thought to be most relevant for a country like Canada[15] this survey will focus on it and leave a review of the R&D literature (and its implications for small countries) for another day.

In this section a brief review is first provided of the endogenous growth literature where human capital is the engine of growth, focusing on quantitative estimates. The approach will be to trace the evolution of this literature, highlighting the different views and examining their consequences. Next, some results from three human capital endogenous growth CGE models are provided. As will be seen, the results do not lend themselves to the same amenable comparisons as the neo-classical growth models.

Quantitative impacts of the effects of tax policy in human capital models of endogenous growth

Two views on tax policy-growth effects

One of the first studies to examine the effects of tax policy in an endogenous growth framework is Lucas (1990). The paper develops a representative agent closed economy model of the U.S. economy with elastic labour supply. Growth is rendered endogenous by the inclusion of human capital in production. The key feature is that human capital production, which is untaxed, requires only existing human capital (and time) as inputs.

Using 1985 as his benchmark year, Lucas calculates the steady-state changes induced by capital tax reductions with the labour tax rate adjusting to maintain budget balance. Reducing the 36% capital tax rate to 30% results in a 7% increase in the long run capital stock and no change whatever to the growth rate. Moreover, eliminating the capital tax results in a 33.7% increase in the capital stock and a slight *decrease* in the growth rate of output from 1.5% to 1.47%. The author thus concludes that the growth effects of tax changes are quantitatively trivial while the level effects are substantial. Implicit in the conclusion is that neo-classical growth models provide an appropriate assessment of the effects of tax policy.

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[15] There is reason to believe that the two other engines, innovation through R&D and government spending on public infrastructure, may be somewhat less important for a country like Canada. In the case of government spending on infrastructure, the literature suggests that significant growth effects can arise when government involvement is initially low but that too much government intervention can have adverse effects. In the case of Canada, it appears likely that the significant growth effects have already been reaped. With respect to innovation and R&D, some evidence suggests that benefits may be lower in small economies (see Grossman and Helpman (1989)).

It is important to point out what is driving this result. Roughly speaking, it arises because changes in labour taxation equally affect both the cost of investment in human capital (changes in today's wage) and its benefits (changes in tomorrow's wage). This leaves the human capital choice more or less unaffected and precludes significant growth effects resulting from changes in wage taxation. In fact, if labour supply is inelastic wage taxation has no effect on growth. The non-zero effect Lucas obtains comes from the fact that labour supply in his model is slightly elastic.

While Lucas (1990) is the benchmark paper for the view that tax policy does not significantly affect the growth rate, King and Rebelo (1990) is the benchmark paper for the opposite view that modest variations in tax rates are associated with significant variations in long-run growth rates.

Their model differentiates itself from the Lucas model in five significant ways. First, they use Cobb-Douglas production functions while Lucas uses a CES. Second, labour supply is inelastic. Third, human capital is produced using both human capital and physical capital (as well as time) as inputs. Fourth, the inputs into human capital production are taxed. Fifth, they allow both human and physical capital to depreciate. Their model is a closed economy model calibrated to accord with the long-run evidence for the U.S. economy. Taxes are imposed on the sectoral outputs of the final goods sector and the human capital sector[16]. Like Lucas (1990), King and Rebelo (1990) focus on steady-state changes. In their benchmark case, they find that raising taxes in both sectors[17] from 20% to 30% reduces the growth rate by 1.52 percentage points. If capital taxes alone are increased from 20% to 30%, the growth rate falls by a more modest 0.52 percentage points. Unfortunately, it is unclear how tax simulation results from this model would rank according to either their efficiency effects or their impacts on output. A rough estimate[18] suggests that capital and labour taxes are fairly close with respect to their effect on the growth rate of output but a definitive answer would require simulations that conduct revenue-equivalent shocks. Nothing can be inferred about an efficiency tax ranking.

The two endogenous growth models described above were the first in a spiralling sequence of papers examining the quantitative impacts of fiscal policy on the long-run growth rate. Papers by Jones, Manuelli, and Rossi (1993), Pecorino (1993,1994), Laitner (1995), Mendoza, Milesi-Ferretti, and Asea (1997), and Kim (1998) are a few examples. Although all these authors use similar frameworks (in line with Lucas (1990) or King and Rebelo (1990)) and calibrate their model to the U.S. economy their quantitative conclusions with respect to the effects of tax policy on growth greatly differ. Since none of these papers offer any explicit tax ranking or

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[16] Which, for constant returns to scale technologies, is equivalent to taxing inputs at equivalent rates.

[17] The tax revenue is used to finance lump-sum transfer payments.

[18] The reasoning is as follows. Capital produces one third (and labour two thirds) of output in all sectors. Both inputs are taxed at the uniform rate of 20% in all sectors so that tax revenue from each factor input must be proportional to its output share. Raising both taxes by 10 p.p. produces a fall of 1.52 p.p. in the growth rate. A 10 p.p. rise in the capital tax reduces growth by 0.52 p.p. If there were no interactions (although clearly there are) one could infer that a 10 p.p. rise in the wage tax accounts for the other 1.00 p.p. However, based on the information from factor shares, this shock would be twice as expensive making it roughly as potent on a per dollar basis.

insight (for the purpose of this discussion) beyond those highlighted in Lucas (1990) and King and Rebelo (1990) I have chosen to gloss over this part of the literature. Rather, the findings of Stokey and Rebelo (1995) who conduct a thorough survey are summarized here. Their objective is to assess which model features and parameters are important for determining the quantitative impact of tax reform.

On the determinants of tax policy growth effects

The key findings of Stokey and Rebelo (1995) are that factor shares in production of human and physical capital, the elasticity of intertemporal substitution, the elasticity of labour supply, and depreciation rates are the parameters of import for conclusions concerning growth rates. In addition, the tax treatment of depreciation and the tax treatment of inputs into the sector producing human capital are also of critical importance for determining growth effects. Thus, of the five characteristics differentiating King and Rebelo (1990) from Lucas (1990), the inclusion of physical capital in the human capital production function, the taxation of inputs used in the production of human capital, and allowing human capital to depreciate are those that account for the differences in the estimated growth effects of public policy.

Stokey and Rebelo (1995) also highlight that the sensitivity of results to the parameters related to human capital formation (factor shares, depreciation rates, and effective tax treatment) is particularly troublesome since estimating these parameters is very problematic and, as a consequence, good information about their values is not readily available.

In the face of inconclusive theoretical evidence, researchers have turned to the empirical evidence for guidance. Recent efforts have focussed on developing econometric tests aimed at determining the effectiveness of tax policy in altering long-run growth. Although this is a fascinating body of knowledge it goes beyond the scope of this inquiry. Suffice it to say that in a recent survey Myles (2000) finds that "Although empirical tests of the growth effect face unresolved difficulties, the empirical evidence points very strongly to the conclusion that the tax effect is very weak."[19]

As was surely noticed, the above analysis was restricted to closed economies. It is unclear whether tax policy plays out in a significantly different fashion in small open economies. Although King and Rebelo (1990) address the issue, they use the textbook small open economy assumption and produce results that are not very credible. For example, when they assume a small open economy rather than a closed economy, the 0.52 percentage point reduction in the growth rate resulting from a 10 percentage point increase in capital taxes becomes a staggering 8.6 percentage point reduction! Yet again, the task of determining the appropriateness of transposing closed economy results to Canada is left for future work. That said, both the closed and open economy frameworks have been used to model Canada.

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[19] Easterly and Rebelo (1993), Stokey and Rebelo (1995), Agell, Lindh and Ohlsson (1997), and Mendoza, Milesi-Ferretti, and Asea (1997) are papers that support this conclusion.

Tax ranking results from the endogenous growth literature

Mérette (1996, 1997) and Xu (1996, 1997)

In OECD (1997) the Department of Finance provided some simulations from models where small, but significant, growth effects arise. In this paper results from two endogenous growth models (Mérette (1996, 1997) and Xu (1996, 1997)) are compared. Although Mérette uses an open-economy overlapping-generations framework and Xu uses a closed-economy representative-agent framework, growth in both models is driven by investment in human and physical capital and public infrastructure. Both models are calibrated for Canada, France, and Sweden and both are used to simulate the long-run impact of a 1%-of-GDP reduction in different types of taxes. The tax reduction is either offset by deficit-neutral adjustments in another tax or lump sum transfers. The results of the long-run GDP growth rate impacts for all three countries are reported in Table 6.

Table 6: Long-Run Real GDP Percentage Point Growth Rate Impacts of Alternative Deficit-Neutral 1%-of-GDP Tax Shocks

	Mérette (1996, 1997)			Xu (1996, 1997)		
	Canada	France	Sweden	Canada	France	Sweden
Shift from capital to sales taxes	0.036	0.023	0.032	0.030	0.025	0.048
Shift from capital to labour taxes	-0.022	0.025	-0.016	0.012	0.008	0.063
Shift from labour to sales taxes	0.000	0.035	0.027	0.041	0.06	0.056
Cut in capital taxes and initial transfers	0.053	0.006	0.065	0.040	0.032	0.041
Cut in labour taxes and initial transfers	-0.036	-0.103	-0.014	0.077	0.116	0.130
Cut in sales taxes and initial transfers	-0.045	-0.120	-0.089	0.022	0.022	0.026

OECD (1997) concludes that: "The endogenous growth model simulations generally suggest that capital taxes are more distorting than either wage or sales taxes. Sales taxes are less distorting, although not much less so than labour income taxes."[20-21] However, OECD (1997) goes on to state that their conclusion does not hold uniformly across model and country assumptions.

Several observations are in order.

First, in the tax shifting experiments, one tax rate is reduced permanently while the other is increased permanently but all government spending subsequently adjusts in order to maintain deficit neutrality. In the tax cut experiment with offsetting lump sum transfers it is only the initial shortfall in government revenue that is offset by lump sum transfers; subsequently all government spending adjusts to maintain deficit neutrality. Since government spending can affect growth in both these models, the subsequent adjustments are important.

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[20] OECD (1997), p.12.

[21] In this study, the tax distortion is defined with respect to its effect on steady-state output growth.

Second, results vary across frameworks, countries, and methods used to offset the tax cut.

A. The results obtained by Mérette (1996, 1997) for Canada and France in the case of the shift from capital to labour taxes indicates that such a policy reduces growth by 0.02 p.p. in Canada but raises it by 0.03 p.p. in France. This difference illustrates how varying the setting can affect results even within a given theoretical framework. In this case the discrepancy results primarily from the different demographic structures in both countries.

B. The large difference for Canada between the two models for a shift from capital to labour taxes also stands out. Note that, for Canada, both models yield similar results with respect to a shift from capital to sales taxes. In Xu (1996, 1997), shifting to labour taxes (instead of sales taxes) raises long-run growth to a lesser extent because a higher wage tax reduces the incentive to invest in human capital more than a higher sales tax. Although this is also the case in Mérette (1996, 1997), the detrimental effect of labour taxes is reinforced because retirement is taken into account. Since retirees do not pay labour taxes the burden of the tax falls entirely on the current and future working-age population, affecting the real wage more than in a representative agent framework.

C. Within the Xu framework, offsetting capital tax cuts with a rise in labour taxes raises the growth rate but a cut in labour taxes (offset by lump sum transfers) is almost twice as beneficial as a similarly offset cut in capital taxes. This paradoxical result arises from the way in which government budgets are maintained after the initial period, as explained above.

Third, although not report here, OECD (1997) also presents a ranking for three other types of spending adjustments. Simulations are presented where initial public good spending, initial human capital spending, and initial changes in all government spending offset the tax reductions. The results are also mixed, with rankings also varying between countries, frameworks, and the type of government spending offsetting the tax reduction.

Fourth, the authors do not report any sensitivity analysis. As highlighted in the previous section, results from endogenous growth models are very sensitive to the choice of parameters (although it is unclear how sensitive the ranking would be) and there is much uncertainty concerning the appropriate choice. This raises the possibility that for an alternative (but equally plausible) set of parameters significantly different results could be obtained.

Fifth, the growth effects, although small, are not insignificant. For example, the 0.13 p.p. change reported by Xu for Sweden in the case of a cut in labour taxes and initial transfers is quite large for a 1%-of-GDP tax shock. However, the differences between the growth effects are smaller. For example, for Canada, the growth rate for a cut in labour taxes is only 0.037 p.p. greater than that of a capital tax reduction (when lump sum transfers adjust).

Sixth, it is unclear what the tax ranking would be if the ranking were based on efficiency measures and the transition were taken into account.

The bottom line is that, the ranking in terms of the impact on steady-state output leans towards an agreement with the results from the Canadian neo-classical growth models (see Table 1)[22] but results vary across frameworks, countries, and the way in which the government maintains budget balance.

Devereux and Love (1994)

Devereux and Love (1994) use the King and Rebelo (1990) framework to examine the issue of factor taxation in the U.S. Unlike King and Rebelo (1990), transitional dynamics and the work-leisure decision are taken into account. Furthermore, taxes are imposed on factor returns rather than industry output. In fact, taxes are only levied on the factor inputs of the final goods sector. That is, inputs into human capital production are not taxed. In addition, they examine the effects of tax regime changes that are equivalent on a present value government revenue basis. Thus, these simulations allow an explicit tax ranking. They consider revenue equivalent increases in the capital, wage, and consumption taxes[23]. The impacts of each tax on the steady-state growth rate of output are reported in Table 5.

Table 5: Steady-State growth effects of revenue-equivalent policies

	Steady State change in the growth rate (percentage points)
Capital tax increases	-0.2
Income tax increases	-0.2
Wage tax increase	-0.2
Consumption tax increase	-0.1

As can be seen, although the growth effects are not insignificant, the differences in growth rates are negligible. Based on the results the authors conclude that the transitional dynamics represent an important element in the evaluation of the overall impact of taxes. Indeed, the authors find that there is a dramatic difference between the various policies in the transition. Taking the transition into account, Devereux and Love (1994) compute the welfare costs of the above tax increases. They find that the capital tax is by far the least efficient method of generating revenue followed by wage and consumption taxes. Their ranking of welfare costs is in accord with the consensus from the neo-classical literature.

It need be emphasized that the transitional dynamics on which the welfare cost calculations are based are limited and somewhat hard to interpret. Because the authors assume perfect mobility of capital and labour between the final goods and human capital producing sectors, the entire transition lasts only one period. In particular, the high welfare cost of capital taxes occurs due to the large drop in consumption resulting from a massive, one-period shift, away from final good production and into human capital production. It is unclear whether such a result would be robust if the perfect factor mobility assumption were relaxed.

Nonetheless, the general idea that transitional dynamics will dominate when growth effects are similar and that this will result in a ranking in accord with the neo-classical growth ranking appears sound.

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[22] Although one is a ranking in terms of level effects while the other is in terms of growth effects.

[23] All tax increases are equivalent to an increase from the benchmark 20% income tax to a 25% income tax.

Comparing experiments from human capital endogenous growth CGE models

In general, three points stand out in the above discussion. The first point is that there is a split in the endogenous growth literature as to the effectiveness of changes in tax policy on the growth rate of output.

Second, if changes in tax policy do not affect the growth rate of output or if the effect is uniform across tax measures, then the standard efficiency ranking from the neo-classical growth literature continues to hold: capital taxes are least efficient, followed by labour taxes, followed by consumption taxes. However, this efficiency ranking need not correspond to a ranking based on GDP growth effects.

Third, the literature is mute on the efficiency tax ranking that would prevail in a context where taxes significantly affect the growth rate and the differences between the growth effects are non-trivial. Although some studies offer a tax ranking based on growth effects, their meaning for an efficiency ranking is nebulous. In terms of a tax ranking based on growth effects, results indicate that reducing capital or labour taxes has a greater impact on steady-state growth than reducing consumption taxes. However, although OECD (1997) reports that capital taxes generally rank ahead of wage taxes, the ranking between capital and labour taxes varies across frameworks, countries, and methods used to offset the tax cut.

IV. Concluding Remarks

It is important to note some of the more important omissions from this survey and provide some caveats regarding results from general equilibrium models.

An important sphere of models that incorporate uncertainty and market imperfections has been ignored in this study. It would be very useful to know whether the general consensus neo-classical tax ranking is preserved when uncertainty and imperfections are introduced. Furthermore, results from the endogenous growth literature based on R&D and innovation have not been reviewed in this study. Although this literature may be more relevant for large economies than for small open economies, it would nonetheless be worthwhile to investigate it.

It is also important to realise the broader limitations of a survey that focuses uniquely on results from the general equilibrium literature. Although general equilibrium models are calibrated to actual economies and use elasticity estimates from the empirical literature, they are no substitute for empirical work. Rather, general equilibrium studies of tax distortions should complement empirical studies that directly estimate the impact of taxation. Furthermore, general equilibrium analysis focuses uniquely on the efficiency criterion for policy evaluation. Efficiciency, of course, is not the only criterion according to which a tax system should be assessed. Equity, in particular how the tax system affects the distribution of income, is a crucial consideration. In addition, the administrative burden imposed on government and the compliance costs imposed on taxpayers also need to be taken into account.

In the end, general equilibrium models are most useful for imposing structure on the way one thinks about tax policy and for providing insight on the key channels through which taxes operate. They also allow the comparison of several alternative policies within a unified framework. However, models are highly stylized representations of our economy and will

invariably fail to model several key aspects of relevance. Thus, although they are excellent tools for providing general guidance to policy makers, they will never provide definite answers to tax policy questions.

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